

## **ATTACHMENT A**

# **DESICCANT, DEHUMIDIFYING ELEMENT AND MANUFACTURING**

## **METHOD FOR THE SAME**

### **TECHNICAL FIELD**

The present invention relates to a desiccant, dehumidifying element  
5 and a manufacturing method for the same.

### **BACKGROUND ART**

A humidity exchanger element dehumidifies gas by a reaction  
between a base and silicate aerogel such as aluminum oxide-silicate or  
10 titanium silicate / titanium-aluminum silicate.

According to US Pat. No. 5, 505, 769, the elements can be included  
in a sheet composed of inorganic fiber, or can be included in a device  
formed by the sheet.

However, the humidity exchanger element needs increased  
15 regeneration temperature (approximately 90~150°C). A sorption capacity  
of the element is limited and has high pressure loss, and moisture of  
content of supply air for being dehumidified is limited . Also, a sorption  
capacity of the humidity exchanger element is decreased over time, that is,  
the element is greatly influenced by aging.

20 Also, nucleus and bio-film are formed while the element  
dehumidifies, thereby closing pores of the humidity exchanger element.

According to G. Heinrich's paper entitled "sorption-supported  
air-conditioning" published by the C.F.Müller Publishing Company in 1997,  
the dehumidifying element is made by containing lithium chloride in

corrugated cardboard, wherein hygroscopic characteristics of the lithium chloride are used for dehumidifying.

~~However, the lithium chloride is volatile by air flow contacted with the dehumidifying element, and as a result, the dehumidifying characteristics of the element are deteriorated while it is used.~~

Also, the humidity exchanger element of the air.

That is, lithium chloride is dissolved in a tropical climate or subtropical climate due to a limited sorption capacity of the element, so that the element can not be used. The base is discharged by steam and cellulose does not sufficiently absorb water due to its limited capacity, so that the dehumidifying element becomes wet.

### **DISCLOSURE OF THE INVENTION**

Therefore, an object of the present invention is to provide a dehumidifying element which maintains hygroscopic characteristics regardless of aging, and high humidity absorbing rate while needing a small amount of energy for regeneration and a method for fabricating the same. To achieve these and other objects and advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is provided a dehumidifying element which includes a super absorbing polymer (SAP), and a hygroscopic base.

There is also provided a method for fabricating a dehumidifying element comprising: selecting a salt solution; drying a super absorbing polymer (SAP), contacting the dried SAP with the salt solution; and drying

a hydrogel generated by the contact between the SAP and the salt solution.

There is also provided a method for fabricating a dehumidifying element comprising: engaging a SAP to a carrier; drying the carrier to which the SAP is engaged; selecting a salt solution; contacting the carrier to which the SAP is engaged with the selected salt solution; and drying the carrier to which the SAP is engaged.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a longitudinal sectional view showing a porous carrier including fibers and granules having a super absorbing polymer (SAP), in which the granules are applied to an upper portion thereof;

Figure 2 is a longitudinal sectional view of a porous carrier having a wave shape of a trapezium and formed by a structured sheet;

Figure 3 is a perspective view of the porous carrier of Figure 2; and

Figures 4A, 4B, and 4C are schematic views showing methods by which three dimensional channels are generated in which the plural porous carriers are structured and/or flat sheets are arranged.

### **MODE FOR CARRYING OUT THE PREFERRED EMBODIMENTS**

The present invention will now be described with reference to accompanying drawings.

The dehumidifying element according to the present invention includes a super absorbing polymer (SAP), so that a quantity of water

having a weight several times that of the dehumidifying element can be absorbed. When the relative humidity of the gas is more than 40%, hygroscopic characteristics can be compared with a silicate dehumidifying element.

5           Also, a hygroscopic base such as lithium chloride is used on the dehumidifying element with the SAP. It has been discovered that the hygroscopic base such as lithium chloride has an excellent bonding force with the SAP (it is assumed that the bonding is performed by substitution of  $\text{Na}^+$  by  $\text{Li}^+$ ).

10           That is, by the bonding with the SAP, the hygroscopic base is prevented from being made volatile by air flow. At the same time, the hygroscopic characteristics of the dehumidifying element are improved by the hygroscopic base.

          Also, in case that the SAP is cross-linked, the SAP has an improved  
15   ability to absorb the base.

          In combination with the hygroscopic base such as the SAP and the lithium chloride, a concentration of the hygroscopic base in solution used at the time of fabrication influences an intensity of hygroscopic effect.

          That is, if solution of too high concentration is used to contact the  
20   SAP with the hygroscopic base, the salt solution is not absorbed at all by the SAP or is absorbed incompletely. That is because the intensity of the hygroscopic effect of the hygroscopic base is influenced not by the amount of the base but by the concentration of the base in solution.

~~According to an experiment, the dehumidifying element absorbs humidity from gas, and is regenerated with less energy than that of the prior arts.~~

In the present invention, the preferable SAPs include polymers and  
5 copolymers in which acryl acid and acrylamide are weakly cross-linked,  
and propfpolymers of starch, cross-linked amylum, and cellulose  
derivative.

The dehumidifying element including the SAP can be fabricated to  
have a predetermined shape, can be contained in a container formed of  
10 material which permits gas to pass, or can be contained in a porous carrier  
or attached to an outer surface of the porous carrier. That is, the  
dehumidifying element can be constructed variously.

The dehumidifying element including the SAP can be formed with  
granules, and the dehumidifying element formed with the granules is  
15 contained in a container through which air passes or fixed on a carrier  
having a predetermined shape.

In case that the dehumidifying element is formed with granules, a  
particle diameter of the respective granules is selected in a range of  $0\mu\text{m}$   
~ $10,000\mu\text{m}$ ; grain fraction in a range of  $1\mu\text{m}$  ~ $5,000\mu\text{m}$  is more preferable,  
20 and grain fraction in a range of  $20\mu\text{m}$  ~ $1,000\mu\text{m}$  is most preferable.

The base of the SAP is a water swelling polymer and/or copolymer  
based on (methyl-)acryl acid, (methyl-)acrylonitrile, (methyl-)acrylamide,  
vinyl-acetate, vinyl-pyrrolidone, vinyl-pyridine, maleic acid (anhydride),  
itaconic acid (anhydride), fumaric acid, and vinyl sulfone acid, base,

amide, N-alkyl derivative, N, N-dialkyl derivative and five-acid ester which can be polymerized, or natural ingredients such as a product made of rubber, that is, carboxymethyl cellulose, xanthan alginate, gum Arabic, hydroxyethylcellulose, methylcellulose, starch and amyllum derivative, and  
5 a product of said components combined or partially cross-linked.

When the dehumidifying element including the SAP is realized as fibers, it can be used in many fields. Especially, if the porous carrier includes the dehumidifying element including the SAP, the dehumidifying element can be realized as a textile, meshed textile, knitted fabric, knit, or  
10 bonded fabric. It is also possible to combine the aforementioned embodiments of the porous carrier.

Methods for providing the dehumidifying element including the SAP in the carrier or on a surface of the carrier include a method for coating the dehumidifying element on the porous carrier or a method for inserting the  
15 dehumidifying element in the porous carrier.

Preferably, by realizing the porous carrier as a fiber composite formed of natural fiber and artificial fiber, humidity carrying characteristics of the natural fiber and mechanical characteristics of the porous carrier formed by the artificial fiber can be improved.

20 The porous carrier can be formed with a single layer or multiple layers, or can be flat or structured. Herein, if the porous carrier is formed with one or plural sheets, it is formed as a dehumidifying body along the periphery of which air flows along, or which air passes through. More preferably, the sheet is structured by forming a wave-shape of the sheet as

a trapezoid or a triangle in a horizontal sectional surface. Then, plural and smooth sheets are arranged in such a method that spatial 3- dimensional channels are generated. Through the channels, air from which humidity will be removed is guided.

5           Then, the hygroscopic characteristics of the element fabricated in the 3-dimension shape can be realized by selecting the salt solution. Regardless of the realization form that the SAP takes a granular form or the SAP is included in the carrier, by drying the SAP at first, the SAP can absorb the salt solution much more. According to this, the SAP can be  
10       contacted to the hygroscopic base. The SAP is provided with the hygroscopic base by contacting the salt solution with the SAP. The element composed of the carrier including the hydrogel generated by contacting the granules with the salt solution or SAP is dried, thereby being converted into a state to absorb humidity.

15           If the SAP is realized as loose granules, the granules are classified before contacting with the salt solution. According to this, uniform characteristics of the element can be realized. Likewise, if the SAP is coagulated after final drying, the granules are crushed, thereby newly classifying finally in any case.

20           If the carrier including the SAP is contacted to the salt solution, dried slowly, and the drying temperature is smoothly increased, a smooth regeneration is possible and thus the salt solution is excellently absorbed by the SAP. It has been observed that the salt solution was not perfectly absorbed when the carrier was to be dried at the highest regeneration



temperature.

Especially, the salt solution used to fabricate the dehumidifying element is selected including 5-15wt% of hygroscopic base concentration. In this case, an intensity of the SAP modified with the hygroscopic base in a range among too high an ion concentration and limitation variables of super absorption can be attained at an optimum state. That is, the hygroscopic base of a maximum amount can be contacted to the SAP by making the base concentration as 5-15wt%, or preferably as 10wt% . The reason is because the salt solution is not absorbed perfectly by the SAP in case of too high concentration, because base ions are not perfectly absorbed when the base concentration is low due to too high an ion concentration, and because an absorption power of the SAP for liquid is exceeded.

If the carrier including the SAP of a granular form is contacted with the salt solution, and the absorption power for the salt solution is too strong, the granule particles are coagulated. Therefore, preferably, the carrier is contacted to the salt solution in several stages according to the fabrication steps of the carrier. At this time, at each stage, the carrier is contacted by a part of the salt solution, and the contact is performed by drizzling, sprinkling, spraying, etc.

#### Preferred embodiment

Figure 1 is a longitudinal sectional view of the dehumidifying element according to the present invention.

As shown in Figure 1, the dehumidifying element of the present invention is composed of a porous carrier 2 to the surface or the inside of which SAP is attached. The SAP is formed in the porous carrier or at a surface thereof as granular particles 1.

5           The granular particles 1 include the SAP, and the SAP is contacted to a hygroscopic base (not shown). At this time, the carrier 2 consists of fiber composed of natural or composite polymer and a filament. Further, the carrier 2 includes fibers 3 containing the SAP therein, in which the fibers 3 are inserted into the porous carrier 2. The fibers 3 are contacted to  
10       the hygroscopic base in a finely distributed form like the granules 1, and can be applied to a surface of the porous carrier 2.

A particle diameter of the granules 1 is approximately identical for all granular particles and is in a range of  $20\mu\text{m} \sim 1,000\mu\text{m}$ . Less preferably, but always suitably, a diameter of grain fraction is in a range of  $1\mu\text{m}$   
15        $\sim 5,000\mu\text{m}$ , in which particles of  $20\mu\text{m} \sim 1,000\mu\text{m}$  are basically considered. The SAP forming the granules includes polymer and copolymer in which acryl acid and acrylamide are weakly cross-linked, and amyllum and cellulose derivatives corresponding to propfpolymer of starch and cross-linked.

20           Also, the granules 1 having a hygroscopic base as a finely distributed shape can form the carrier itself without an additional carrier and perform a dehumidifying function. Also, the granules 1 can be applied on the surface of the porous carrier 2 by coating and included in the porous carrier 2. Also, in case that the porous carrier 2 is a fiber composite, the

SAP can be integrated in the carrier 2 as a part of the fibers.

The fiber composite is a matrix and includes natural fibers or one or plural artificial fiber materials corresponding to reinforcing fibers. The artificial fiber material improves mechanical characteristics of the porous carrier 2 or the fiber composite, and the natural fiber carries humidity better.

Also, the natural fiber stores its humidity, that is, water vapor, water or aqueous solution. The porous carrier composed of fiber or filament includes textile, meshed textile, knitted fabric, knit, a combination therebetween, bonded fabric, etc.

The SAP is contacted to the hygroscopic base by soaking a water-based solution of the hygroscopic base into the granules of the SAP or the SAP fibers, drizzling, sprinkling or by other methods. Herein, the SAP absorbs the salt solution by its own absorption characteristics.

As a modification method, the modification of the SAP, in other words, contacting the SAP with the salt solution, the SAP can be modified before the granules of the SAP or the SAP fibers are included in the carrier or at a surface of the carrier, or can be modified after the SAP granules or the SAP fibers are already included in the carrier or at the surface of the carrier.

If the porous carrier is modified in several fabrication steps, structured, or arranged, the modification of the SAP and the salt solution can be performed at any fabrication step in consideration with a time point of the most preferable modification.

In order to modify the SAP granules or the SAP fibers, first of all, the salt solution has to be selected. The salt solution includes a strong hygroscopic base such as lithium chloride, magnesium chloride, calcium chloride, or lithium bromide, and includes water as solvent.

- 5           The salt solution is completely desalinated, deionized, and distilled, wherein a base concentration is 5~15wt% and a maximum concentration is 15 wt%.

~~If the SAP granules are modified at an outside of the porous carrier formed of fiber composite or web bunch, the granules need to be classified to have uniform size distribution and equal granule characteristics on the basis of very broad size distribution. In this case, a sieve classifier is preferably used.~~

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- 15           In order to maintain residual humidity of the SAP minutely and contact with the salt solution later, the granules or fibers are dried to absorb the SAP granules or the SAP fibers. In this case, a vacuum drier is used. The vacuum drier applies a load of heat to the granules very minutely at the time of drying, thereby considering a temperature safety of maximum long term life of the SAP.

- 20           Then, the dried SAP granules are modified with the salt solution, and can be variously processed. For example, the granules can be provided in the salt solution or the solution can be added to the granules.

After the modification, the hydrogel generated from the SAP granules is dried, and at the same time, the granules are regenerated. The hydrogel can be dried by being applied as a planar layer with a maximum

thickness of 1cm on a plate. According to this, a lump formation at the time of drying can be prevented. However, since solidification always follows, a proper crushing is necessary. To this end, an impact crusher or a breaker is suitable.

- 5           A new classification is performed in order to maintain the SAP granules generated from the gel, crushed, and modified to provide the hygroscopic base with a uniform size.

          If the SAP granules or the SAP fibers are located in the carrier or thereon before the modification using the salt solution is started, the entire  
10   carrier is dried by considering the heat load transmitting ability of the SAP and the carrier in order to decrease water containing amount to the minimum. The salt solution is selected by a method similar to the aforementioned methods.

          When the porous carrier 2 including the SAPs 1 and 3 is contacted,  
15   it should be considered whether or not the modification is performed in plural stages . The reason is that the granular particles 1 can be solidified in the porous carrier 2 or thereon like the modification of the granules at the time of absorbing the salt solution too strongly. When the solution is contacted with the carrier including the SAP in multiple stages, procedures  
20   such as drizzling, sprinkling, or spraying can be performed. The procedures are very important since the solidification is not removed even by the crushing due to the carrier material.

          Finally, the carrier 2 including the SAP is dried slowly, that is, within one or two days, and at the same time, the drying temperature is gradually

increased during the drying term until it rises almost to the maximum regeneration temperature.

This drying of the carrier 2 including the SAP performed by slowly increasing the temperature maintains the structure of the modified SAP.

- 5 That is, the SAP is not decomposed. The drying method includes a freeze drying, a microwave drying, a normal drying, or a combination drying therebetween.

If the porous carrier is structured and/or arranged by a method that a dehumidifying body is formed, the SAP granules or the SAP fiber  
10 inserted in the porous carrier or applied thereon can be properly modified. The structured porous carrier, as shown in Figures 2 and 3, includes a trapezoid wave shape as a structured sheet, and at the same time, a sheet of a corrugated reed shape has a ripple of 2.5~7mm, an interval length (a), a ripple of 1 ~5mm, and a wave height (b).

- 15 The forming is attained by an embossing process using a rippling or a stamping in heat reaction at a 180°C temperature.

Figures 4A, 4B, and 4C are schematic views showing the respective embodiments in which the plural sheets according to Figures 1 and 2 are arranged by a method such that 3-dimensional channels are generated.

- 20 The channels permit gas from which the humidity will be removed, for example, air, to penetrate or to flow at the periphery.

In Figure 4A, one structure is generated by a combination between flat sheets and shaped sheets. The structure is coiled to the dehumidifying body simply or laminated, thereby properly being arranged like a general

humidity exchanging body.

Figure 4B shows two sheets structured as a trapezoid. The sheets form a honeycombed structure, and form 3-dimensional channels like in Figure 4A. Through the channels, gas from which humidity will be removed  
5 can flow.

Figure 4C illustrates a plurality of layers according to the arrangement of Figure 4B, by which a dehumidifying body having 3-dimensional channels can be formed.

Regardless of the point in time of the modification, that is,  
10 regardless of whether the SPA granules or the SAP fiber is contacted to the hygroscopic base or not, whether the SPA granules or the SAP fiber is contacted to the hygroscopic base with a location in the porous carrier or thereon or not (Figure 1), or whether the modification is started after the porous carrier passes several transformation steps or not (Figures 3, 4B,  
15 and 4C), lithium chloride adjacent on the surface of the SAP permits not only water to be added but also water to be guided inside of the superabsorber.

At this time, preferably, on one hand, the base is spontaneously regenerated as water is guided into the superabsorber. And, on the other  
20 hand, humidity is removed into the superabsorber and thus does not remain on the surface any longer.

### **INDUSTRIAL APPLICABILITY**

As so far described, according to the dehumidifying element and the

method for fabricating the same, hygroscopic characteristics regardless of aging and high humidity absorbing rate are maintained and a small amount of energy for regeneration is required.